LJ-89-17

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SPAWNING BIOMASS OF THE NORTHERN ANCHOVY IN 1989

by

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ADMINISTRATIVE REPORT LJ-89-17

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SPAWNING BIOMASS OF THE NORTHERN ANCHOVY IN 1989

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ABSTRACT

The spawning biomass of northern anchovy (Engraulis mordax) in the central subpopulation on 15 February 1989 was estimated to be 237,000 mt. The low estimated spawning biomass was due to delayed maturation of one-year-old fish (the 1988 year class) caused by cold water temperatures during January and February of 1989. There was no evidence that the low spawning biomass was due to recruitment failure or over-fishing.

INTRODUCTION

Management of the central subpopulation of northern anchovy (Engraulis mordax) by the Pacific Fishery Management Council includes a harvest quota which varies annually as a function of the estimated spawning biomass in each year (Pacific Fishery Management Council 1983). The National Marine Fisheries Service, Southwest Fisheries Center is responsible for annual estimates of the spawning biomass that are used to determine the quota. The purpose of this report is to present the anchovy spawning biomass estimate for 1989.

METHODOLOGY

The Stock Synthesis Model (Methot 1986; Methot and Lo 1987; Lo and Methot, in press) has been used on an annual basis since 1986 to estimate the spawning biomass of northern anchovy. The Stock Synthesis Model is an age-structured model that is parameterized such that indices of relative abundance computed by the model and age composition of the simulated catches agree with available data. Parameters in the model are estimated by means of a composite likelihood function (Methot 1986).

The data used to parameterize the Stock Synthesis Model for northern anchovy are: 1) spawning biomass (EPM) as estimated by the Egg Production Method (Lasker 1985), 2) an index of historical egg

production (HEP) which is related to spawning biomass (Lo 1985), 3) an index (MHEP) of historical egg production modified to account for changes in survey design (Methot and Lo 1987), 4) biomass of schooled fish as measured by the California Department of Fish and Game (CDF&G) using sonar (Mais 1974), 5) age composition data from commercial and survey catches, 6) weight at age data from commercial and survey catches, 7) total catch data, 8) mean monthly sea surface temperatures at Scripps Pier 9) estimated annual abundance of Pacific Mackerel (Scomber japonicus), 10) the fraction of age 1 females determined to be actively spawning by visual examination during CDF&G surveys during late winter, and 11) the fraction of age 1 females determined to be sexually mature by histological examination. Weight at age and age composition data from the Mexican and US commercial fisheries as well as the US survey fisheries are used. Not all data are available for all years (Methot 1986).

The model used for the 1989 spawning biomass estimate was identical to that used for the 1988 estimate except for the following modifications. The first modification was that fishing mortalities were not adjusted on the basis of the age composition data (see Methot and Lo 1987, p. 10-12). This modification makes the parameter estimation procedure conform more closely to likelihood estimation theory. The second modification consisted of eliminating the comparison of the observed and predicted mean values for the EPM biomass during 1980-1985 from the parameter estimation process (the comparison of observed and predicted annual

values of the EPM biomass was not eliminated). This modification reduces the overall emphasis placed on EPM data during parameter estimation because the EPM data are, in effect, used once rather than twice. The effect of these modifications on estimates of the 1989 spawning biomass was investigated and found to be minor (see the Results section).

The third modification to the model was necessitated by discrepancies involving relationships between sea surface temperature, sexual maturity and spawning activity. Lo and Methot (in press) describe functional relationships that are used in the model to predict the proportion of mature one-year-old fish during January-February as well as the proportion of one-year-old fish that are actively spawning during January-February on the basis of mean sea surface temperatures during January-February. On the basis of these relationships, the fractions of one-year-old anchovy that were expected to be sexually mature during 1972 and 1989 were less than the fractions expected to be sexually active. This discrepancy was due to the extremely cold water temperatures that existed during January-February 1972 and 1989 (Table 1). The model was modified so that the proportion sexually active was equal to the proportion sexually mature at water temperatures lower than 12.9° C. Lo and Methot (in press) found it necessary to reduce the fecundity (eggs per gram) of two-year-olds in 1972 because of the probable effect of low water temperatures on fecundity. For the sake of consistency, the fecundity of two-year-olds in 1989 was reduced as well.

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NEW DATA

Environmental Data

The mean sea surface temperature at Scripps Pier during and preceding the spawning season in 1989 was much lower than normal (Table 1). The mean temperature for January-February 1989 (the peak of spawning for northern anchovy) was 12.5° C compared to the long term (since 1960) mean January-February temperature of 14.3° C. Low temperatures during and preceding the spawning season result in reduced spawning biomass because of the effects of temperature on sexual maturity and spawning activity. At 12.5° C, only 5% of one-year-old anchovy are expected to be sexually mature and actively spawning.

Mean sea surface temperatures at Scripps pier during the 1988 fishing season were about average (Table 2). Temperatures during the fishing season are thought to affect the distribution of fish, their availability to the fisheries and the size at age observed in the Mexican fishery (Methot and Lo 1987).

Egg Production Data

Production of eggs by anchovy during January of 1989, as indicated by the MHEP index, was 2.39 eggs/.05 m^2/day (SE = 1.30) and was the lowest value since observed since 1983 (Table 1). This result suggests that the spawning biomass during 1989 was low.

Fishery Data

Monthly catch (Table 3), weight at age (Table 4) and age composition data (Table 5) from the Mexican reduction fishery during April-November 1988 were provided by the Centro Regional Investigacion de Pesquera (W. Garcia, pers. comm.). Monthly catch data from the US fishery (Table 3) were provided by CDF&G (C. Cooney, pers. comm.).

The Mexican reduction fishery harvested 79,230 mt of northern anchovy during 1988 while the US live bait, reduction and non-reduction fisheries harvested 5,656 mt of northern anchovy. The total catch during 1988 was 84,886 mt which can be compared to 129,350 mt in 1987 and 101,175 mt in 1986 (Thomson et al. 1989).

Anchovy taken by the Mexican reduction fishery during 1988 were larger than average. Mean weights at age were larger than average for most age groups in all months (Table 4). This result was surprising since 1988 was not a cold year (cold water is thought to increase the size at age observed in the Mexican fishery because large and older fish remain in the south in order to avoid the relatively cold northern waters, see Methot and Lo 1987 and Lo and Methot, in press).

Anchovy in the 1988 year class (age zero in 1988) recruited to the Mexican fishery earlier and constituted a greater proportion of the total catch than usual. The age composition data for 1988 show unusually high proportions of age zero fish in the second, third and fourth calendar quarters (Table 5). The early appearance

of age zero fish during 1988 and their greater than average size suggests two hypotheses. The first hypothesis is that a successful peak in spawning occurred earlier than the normal period of peak spawning (i.e. the recruits observed early in 1988 may have been due to spawning in November-December 1987 rather than spawning during February-April 1988). The second hypothesis is that the 1988 year class was unusually abundant and/or grew at a rate that was faster than normal.

In the Stock Synthesis Model, recruitment occurs, by definition, at age 0.5 years at the beginning of the third 'pseudo-quarter' (pseudo-quarters are approximately the same as calendar quarters, see below) and age zero fish encountered prior to the beginning of the third pseudo-quarter are assumed to be age one fish that were mis-aged. The age composition data for most years are compatible with this definition because relatively few age zero anchovy are typically observed prior to the second calendar quarter (Lo and Methot, in press). It seems unlikely, however, that the age zero fish observed during May-June 1988 were actually age one because they constituted more than 40% of the total catch during those months. The importance of this apparent discrepancy between the age composition data for 1988, age composition data for previous years and the structure of the model was diminished by grouping the data for 1988 into pseudo-quarters as described below.

Monthly catch, age composition and weight at age data for each year are grouped into pseudo-quarters for use with the Stock Synthesis Model (Methot 1986). Months in each year are assigned

to pseudo-quarters in such a way as to make the catch, age composition and weight at age data for each pseudo-quarter as consistent as possible. Months included in each pseudo-quarter may differ from one year to the next as well as between the US and Mexican fisheries in any particular year. For the 1989 calendar year the data for January-March were grouped to form the first pseudo-quarter. Data for April were used for the second pseudo-quarter and all age zero fish observed in April were assumed to have been age one fish that were mis-aged. Data for May-July were grouped to form the third pseudo-quarter and data for August-December were grouped to form the fourth pseudo-quarter (Tables 3-5). This approach to grouping the data effectively delays the appearance of new recruits until the beginning of the third pseudo-quarter and tends to reduce the estimated abundance of new recruits (age zero fish) during 1988.

Pacific Mackerel

Natural mortality of northern anchovy in the Stock Synthesis Model varies from year to year on the basis of Pacific Mackerel biomass levels. Biomass levels of Pacific mackerel at 1 July during 1964-1969 used in this analysis (Table 1) were estimated by virtual population analysis (Parrish and MacCall 1978). Biomass values for 1970-1976 were set at an arbitrary low level consistent with the condition of the fishery during that period. Biomass values for Pacific Mackerel during 1977-1988 were the same as those used by Lo and Methot (in press) for the 1988 spawning biomass

estimate. Biomass of Pacific Mackerel at 1 July 1989 was estimated by CDF&G on the basis of a virtual population analysis for 1977-1988, average mortality rates and an assumed recruitment level for the 1989 year-class (P. Wolf, pers. comm.).

Unfortunately, it was not possible to update the Pacific mackerel biomass data for 1977-1988 using the new virtual population analysis because of limited time and difficulties in extracting the requisite information using the available software. Results obtained using the Stock Synthesis Model are typically not sensitive to the level of Pacific mackerel mortality (Methot 1986) which suggests that the data used in this analysis probably suffice as an indicator of Pacific mackerel biomass.

RESULTS

The estimated spawning biomass for the central subpopulation of northern anchovy on 15 February 1989 was 237,000 mt which can be compared to 336,000 mt in 1988 and 583,000 mt in 1987 (Figure 1). The precision of the estimated value for spawning biomass is suspect, however, because the effects of water temperatures as cold as those observed during the 1989 spawning season on spawning rates, fecundity and the distribution of the spawning stock are unknown.

The estimated total biomass for northern anchovy on 15 February 1989 was 1,008,000 mt which can be compared to 369,000 mt

in 1988 and 594,000 mt in 1987 (Figure 1). The increase in estimated total biomass was due primarily to the apparently large 1988 year class recruiting to the population (but not to the spawning stock) as one-year-olds in 1989 (Figure 2). The precision of the estimated value for total biomass during 1989 is also suspect because it depends on the availability of young fish to the Mexican fishery at low water temperatures (which has not been precisely quantified) and on the atypical age composition data for 1988. The apparently abundant 1988 year class and high total biomass suggest that the low spawning biomass was due primarily to the effects of cold water on the sexual maturity and spawning activity of one-year-old fish and not due to recruitment failure or over-fishing.

Sensitivity of Biomass Estimates to New Methodology

The spawning biomass for 1988 estimated by Lo and Methot (in press) using data for 1964-1987 (1,009,000 mt) is substantially greater than the spawning biomass estimate for 1988 (336,000 mt) obtained in this analysis. The methods used by Lo and Methot for the 1988 estimate were applied to the data used for the 1989 estimate to determine the extent to which differences in methodology affected the estimated spawning biomass and total biomass. As can be seen in the table below, differences in estimates due to methodology were minor.

Year	Methods Used For 1988 Estimate: Data for 1964-1988[1]	Methods Used For 1988 Estimate: Data for 1964-1989	Methods Used For 1989 Estimate: Data for 1964-1988	Methods Used For 1989 Estimate: Data for 1964-1989[2]
Estimated Spawning Biomass				
1982	429,000	426,000	421,000	419,000
1983	538,000	528,000	546,000	533,000
1984	376,000	374,000	375,000	371,000
1985	530,000	539,000	528,000	532,000
1986	627,000	605,000	626,000	601,000
1987	878,000	596,000	880,000	583,000
1988	1,009,000	352,000	1,013,000	336,000
1989	---------	249,000	---------	237,000
Estimated Total Biomass				
1982	471,000	469,000	465,000	464,000
1983	556,000	545,000	563,000	550,000
1984	382,000	380,000	381,000	377,000
1985	677,000	689,000	678,000	681,000
1966	633,000	611,000	632,000	607,000
1987	901,000	608,000	902,000	594,000
1988	1,298,000	384,000	1,305,000	369,000
1989	---------	1,028,000	---------	1,008,000

[1] Data and method used for 1988 estimate.
[2] Data and method used for 1989 estimate.

These results demonstrate that the low estimated spawning biomass for 1989 was not due to changes in methodology.

Reliability of estimated biomass values for recent years

Results depicted in the table above show that an additional year of data can have a pronounced effect on estimates of spawning and total biomass during recent years (i.e. 1985-1988 in the table). The effect diminishes with time so that biomass estimates for years prior to the third or fourth most recent years (i.e. 1982-1984 in the table) are almost unaffected (Figure 3). This pattern is a typical result in the analysis of catch-at-age data

(Pope 1972) that is generally due to uncertainty about the abundance of young fish and their availability to the fishery (Lo and Methot, in press).

Uncertainty about the biomass of anchovy during recent years is probably primarily due to the absence of auxiliary information about biomass levels during recent years. No HEP egg production data, sonar based estimates of schooling biomass or spawning biomass estimates by the EPM method have been unavailable since 1985 (Lo and Methot, in press). This potential problem is currently under investigation.

ACKNOWLEDGEMENTS

We thank all of our colleagues who contributed energy, data and ideas to this analysis. In particular, we thank W. Garcia (Centro Regional Investigacion de Pesquera) for providing data from the Mexican fishery through the MEXUS-PACIFICO program, C. Cooney (California Department of Fish and Game) for providing data from the U.S. fisheries and P. Wolf (California Department of Fish and Game) for providing projected Pacific Mackerel biomass figures for 1989.

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Table 1. Mean January-February sea surface temperatures at Scripps Pier, Pacific mackerel biomass on 1 July and the Modified Historical Egg Production (MHEP) index (eggs/0.05 m^2/day) for 1964-1969. Standard errors for the MHEP are given in parentheses.

Year	Mean Surface Temp. ($^\circ$ C)	Pacific Mackerel Biomass (10^3 mt)	MHEP	
1964	15.0	53	8.64	(4.59)
1965	13.3	18	8.18	(2.91)
1966	13.8	9	12.85	(5.12)
1967	14.0	5	--	--
1968	14.5	5	--	--
1969	14.3	5	5.43	(1.55)
1970	13.6	5	--	--
1971	13.1	5	--	--
1972	12.8	5	3.45	(0.83)
1973	15.0	5	--	--
1974	13.1	5	--	--
1975	13.2	10	16.71	(3.96)
1976	13.9	10	--	--
1977	16.0	97	--	--
1978	15.7	132	14.66	(6.53)
1979	13.9	292	5.07	(2.19)
1980	15.0	252	2.55	(0.99)
1981	14.6	333	4.74	(1.78)
1982	14.1	359	1.68	(2.03)
1983	15.9	244	1.65	(1.27)
1984	15.0	157	2.57	(1.76)
1985	13.8	457	5.16	(2.16)
1986	15.2	500	7.56	(3.34)
1987	15.0	500	7.23	(2.57)
1988	13.9	290	6.89	(3.42)
1989	12.5	119	2.39	(1.30)

Table 2. Mean monthly sea surface temperatures at Scripps Pier for January 1988 to February 1989. Values given in parentheses are long term averages and standard deviations for months (e.g. the average mean surface temperature for January during 1960-1988 was 14.2° C and the standard deviation for mean January temperatures was 1.1°).

Month	Mean Surface Temp. (° C)
1988	
January	13.7 (14.2, 1.1)
February	14.2 (14.4, 1.0)
March	15.5 (14.7, 0.9)
April	16.8 (15.5, 0.9)
May	17.1 (16.9, 1.0)
June	17.9 (18.2, 1.1)
July	20.9 (19.7, 1.0)
August	20.7 (20.8, 1.1)
September	19.5 (19.7, 1.0)
October	18.5 (18.2, 0.9)
November	14.4 (16.3, 1.1)
December	12.9 (14.7, 1.1)
1989	
January	11.9 (14.2, 1.1)
February	13.1 (14.4, 1.0)

Table 3. Monthly catch data (mt) for the US and Mexican fisheries during 1988. The figures shown include all reported catches (catches by reduction and non-reduction fisheries). Pseudo-quarters are described in the text.

Month	US	Mexican	Total
Pseudo-quarter I			
January	101	0	101
February	199	0	199
March	272	0	272
Pseudo-quarter II			
April	381	401	782
Pseudo-quarter III			
May	620	3,262	3,882
June	729	14,383	15,112
July	1,025	36,541	37,566
Pseudo-quarter IV			
August	989	9,092	10,081
September	558	10,195	10,753
October	275	4,707	4,982
November	400	649	1,049
December	107	0	107
Total	5,656	79,230	84,886

Table 4. Monthly mean weight at age data (grams wet weight) from the Mexican reduction fishery during 1988.[1] Figures in square brackets are sample sizes for 1988. Figures in parentheses are long-term averages for months (e.g. the mean weight of anchovy age I in April during 1964-1988 was 9.8 g). Pseudo-quarters are described in the text.

Month	Age Group 0	I	II	III	IV	V+
Pseudo-quarter II						
April	11.6	15.9	17.4	17.5	20.8	22.1
	[17]	[34]	[18]	[77]	[39]	[9]
	(--)	(9.8)	(12.8)	(15.7)	(18.8)	(19.8)
Pseudo-quarter III						
May	7.0	15.7	17.4	17.6	18.0	21.2
	[171]	[45]	[28]	[58]	[22]	[15]
	(6.9)	(10.3)	(13.2)	(16.0)	(17.8)	(21.5)
June	8.7	17.3	19.9	20.7	21.4	21.0
	[330]	[81]	[107]	[169]	[65]	[19]
	(6.5)	(12.1)	(14.3)	(17.6)	(19.6)	(23.1)
July	8.5	15.1	18.4	18.4	18.1	21.9
	[415]	[69]	[57]	[70]	[29]	[20]
	(6.5)	(11.8)	(14.4)	(15.5)	(17.6)	(21.8)
Pseudo-quarter IV						
August	6.1	17.2	19.0	19.0	20.5	18.7
	[1124]	[95]	[127]	[93]	[43]	[36]
	(6.2)	(12.4)	(15.4)	(17.5)	(19.6)	(18.7)
September	6.9	12.5	19.9	20.7	19.7	18.8
	[1542]	[177]	[35]	[32]	[16]	[4]
	(6.5)	(11.7)	(12.9)	(14.6)	(18.8)	(18.8)
October	7.2	14.4	18.8	20.3	26.2	
	[648]	[36]	[1]	[8]	[4]	
	(7.2)	(11.1)	(13.4)	(14.0)	(15.1)	
November	9.5	11.7	18.3	23.1	22.6	23.7
	[41]	[100]	[8]	[7]	[18]	[3]
	(8.1)	(11.5)	(13.9)	(16.4)	(20.8)	(23.7)

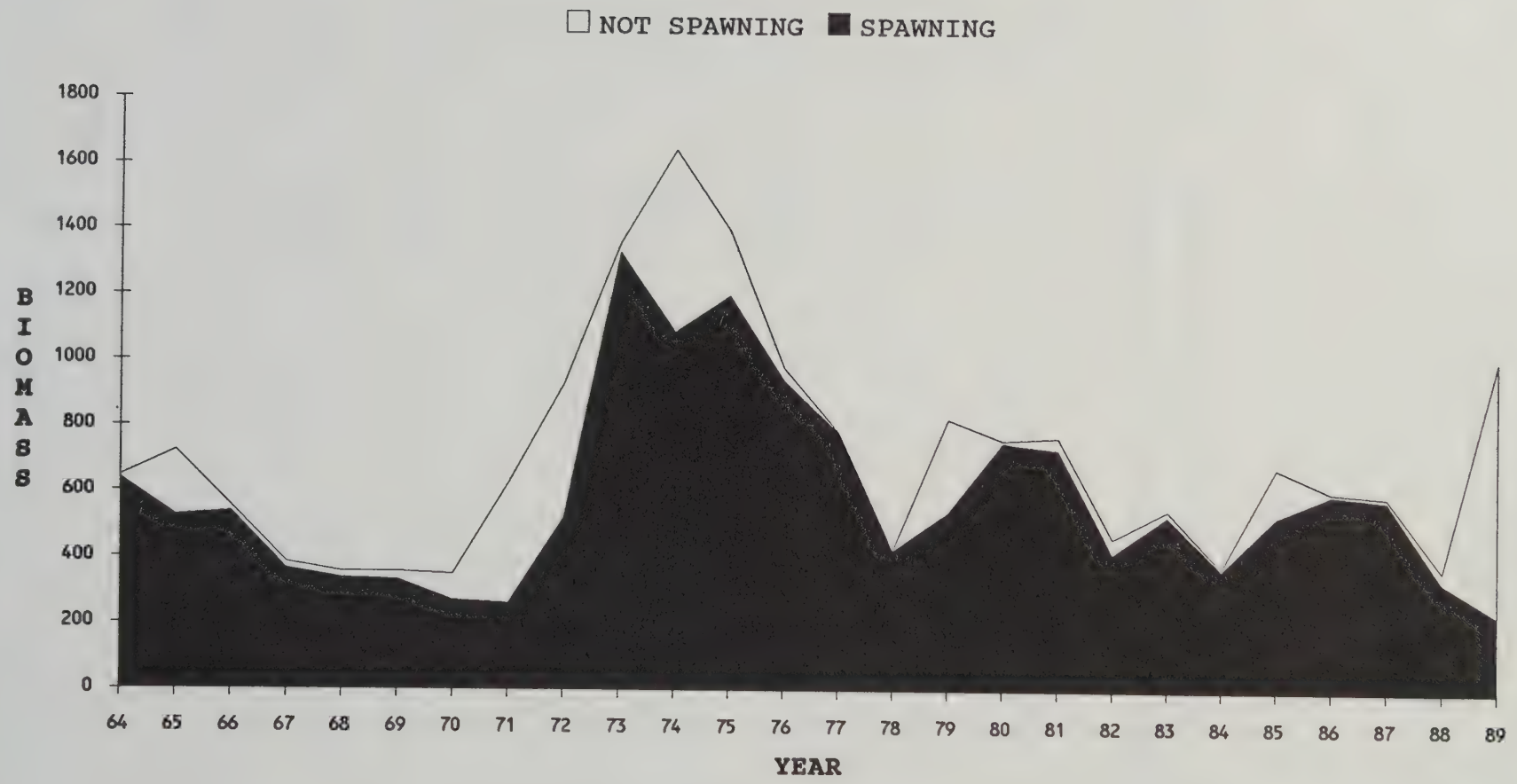
[1] Data provided by Centro Regional Investigacion de Pesquera (W. Garcia, pers. comm.)

Table 5. Monthly age composition data (% by number of each age group in samples) from the Mexican reduction fishery during 1988.[1] Figures in square brackets are sample sizes for 1988. Figures in parentheses are averages for 1983-1987 (e.g. on average, anchovy age I made up 72% of the catch during 1983-1987). Pseudo-quarters are described in the text.

Month	Age Group 0	I	II	III	IV	V+
Pseudo-quarter II						
April	8.8	17.5	9.3	39.7	20.1	4.6
	[17]	[34]	[18]	[77]	[39]	[9]
	(1.3)	(72.2)	(19.2)	(6.1)	(0.9)	(0.3)
Pseudo-quarter III						
May	50.4	13.3	8.3	17.1	6.5	4.4
	[171]	[45]	[28]	[58]	[22]	[15]
	(1.3)	(68.4)	(22.5)	(6.2)	(1.3)	(0.3)
June	42.8	10.5	13.9	21.9	8.4	2.5
	[330]	[81]	[107]	[169]	[65]	[19]
	(9.7)	(64.1)	(20.3)	(4.7)	(0.6)	(0.6)
July	62.9	10.5	8.6	10.6	4.4	3.0
	[415]	[69]	[57]	[70]	[29]	[20]
	(27.8)	(58.1)	(12.5)	(1.5)	(0.1)	(0.1)
Pseudo-quarter IV						
August	74.0	6.3	8.4	6.1	2.8	2.4
	[1124]	[95]	[127]	[93]	[43]	[36]
	(49.8)	(37.0)	(10.9)	(2.0)	(0.3)	(0.0)
September	85.4	9.8	1.9	1.8	0.9	0.2
	[1542]	[177]	[35]	[32]	[16]	[4]
	(63.8)	(22.4)	(11.7)	(1.6)	(0.5)	(0.0)
October	93.0	5.2	0.1	1.1	0.6	0.0
	[648]	[36]	[1]	[8]	[4]	
	(60.7)	(21.3)	(12.2)	(4.5)	(1.2)	(0.1)
November	23.2	56.5	4.5	4.0	10.2	1.7
	[41]	[100]	[8]	[7]	[18]	[3]
	(64.5)	(23.9)	(10.2)	(1.1)	(0.3)	(0.0)

[1] Data provided by Centro Regional Investigacion de Pesquera (W. Garcia, pers. comm.)

Figure 1. Estimated spawning stock biomass and total biomass during 1964-1989. Biomass values are given in units of 10^3 mt.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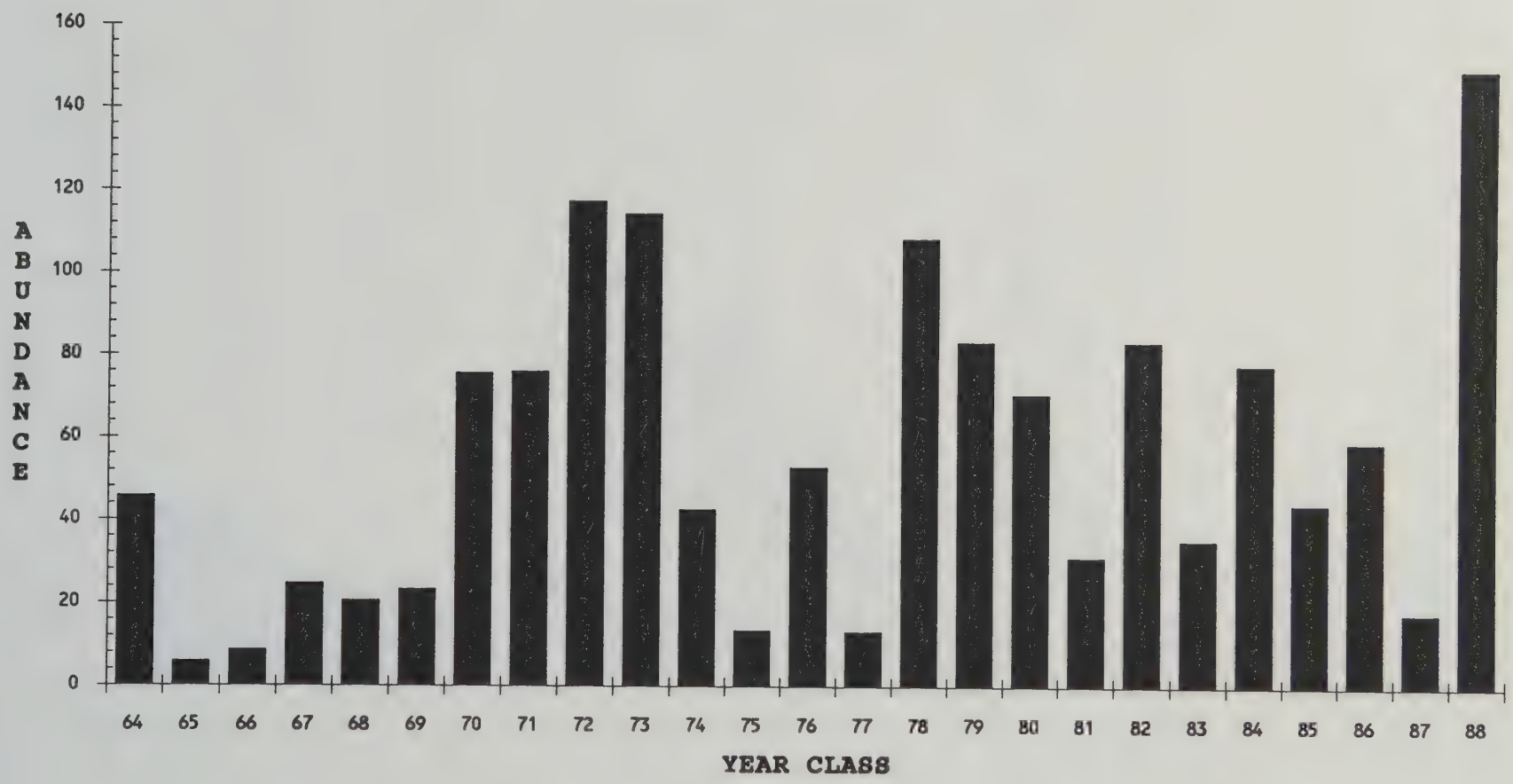
YEAR

Figure 2. Estimated abundance (in units of 10^9 fish) of the 1964-1988 year classes at age 0 on 1 July (e.g. the abundance of the 1964 year class on 1 July 1964 was about 43 x 10^9 fish).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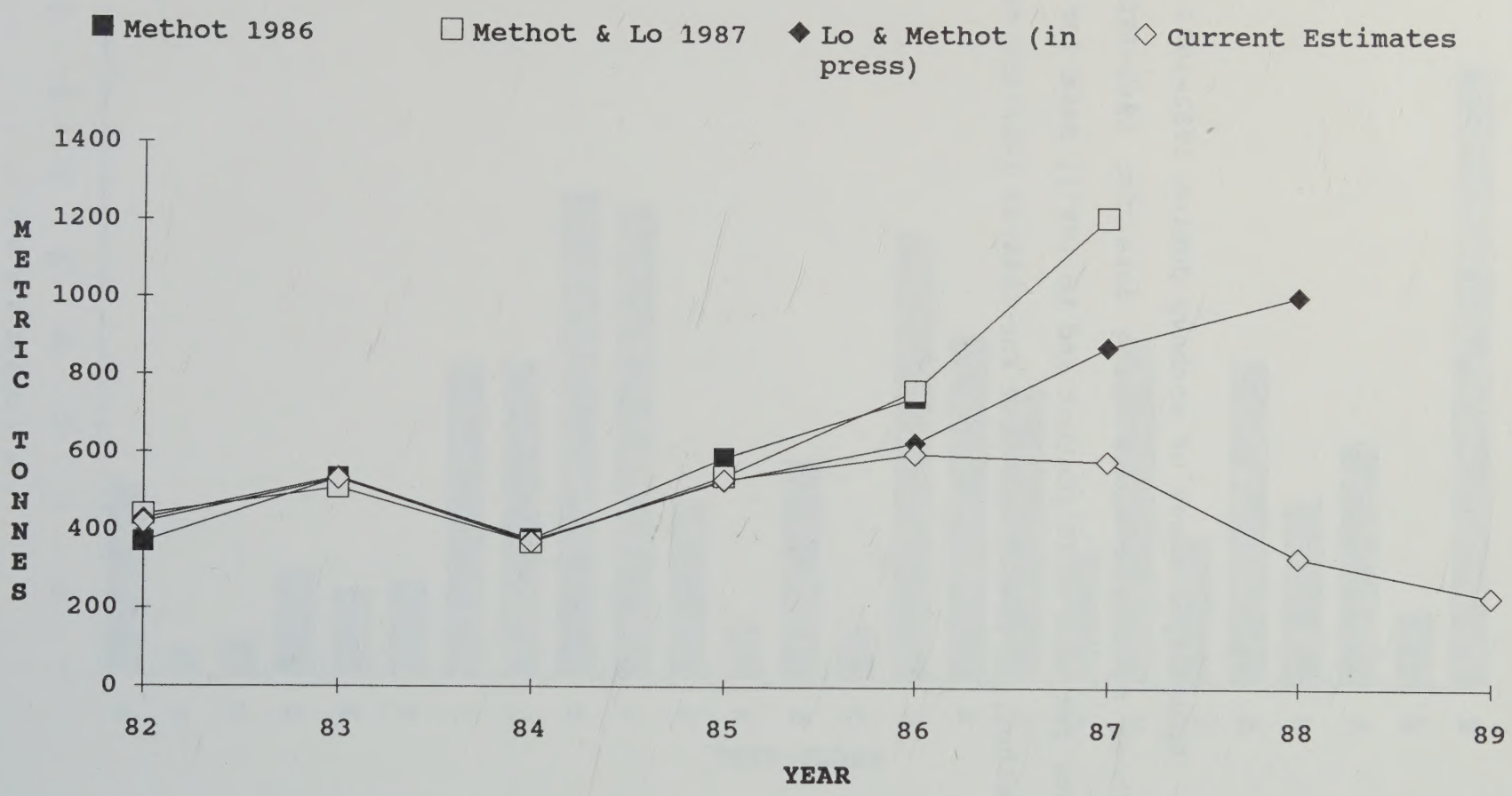
YEAR CLASS

Figure 3. Spawning biomass of anchovy during 1982-1989 estimated by the Stock Synthesis Model using data for 1964-1986 (Methot 1986), data for 1964-1987 (Methot and Lo 1987), data for 1964-1988 (Lo and Methot, in press) and data for 1964-89 (current estimates).


■ Methot 1986
□ Methot & Lo 1987
◆ Lo & Methot (in press)
◇ Current Estimates
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